Advanced Image Processing Techniques for Physics Studies

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Video cameras have recently become diagnostic tools widely used on Joint European Torus (JET) for fusion plasma diagnostic and control. Camera based instruments provide essential information for both the control of the experiments and the physical interpretation of the results. These cameras can produce up to hundreds of kiloframes per second and their information content can be very different, depending on the experimental conditions. However, the relevant information about the underlying processes is generally of much reduced dimensionality compared to the recorded data. The extraction of the relevant information, which allows the full exploitation of these diagnostics, is a challenging task. In the last few years, new tools and methods were developed in order to manipulate this huge amount of data and to retrieve the desired information.

In this framework the methodology of optical flow (OF) has allowed, under certain assumptions, deriving information about the velocity of video objects, associated with different physical phenomena like e.g. instabilities, pellets, and filaments. The implemented method is robust under noise and yield dense flow fields. The OF method was further developed taking advantage of the fact that video streams are usually compressed for storage. MPEG-2 compressed domain information is processed to obtain a very fast and reasonably accurate 2-D motion estimation of the video scenes for the JET diagnostics, whose computational costs are, otherwise, prohibitively high. In this way the OF method can be used for the manipulation of the large JET video databases and, in specific cases, even for real-time data processing.

Different approaches, based on the extraction of structural information from the visual scene, are currently under development for the automatic detection of plasma instabilities which can trigger harmful disruptions. A good rate of correct classifications is obtained using phase congruency (PC), a dimensionless measure of the significance of a local structure in images. The identification of instabilities is based on the evaluation of PC with respect to the reference images which synthetize the instability signature in the video data. PC map is calculated via wavelets using 2-D log-Gabor filters. Finally, a different method is based on the sparse learned representations of video images. The unsupervised dictionary learning process for the sparse image representation, in an overcomplete dictionary, is adapted to the purpose of disruption prediction and identification by incorporating specific discriminative components. Promising results were obtained for instability detection but this approach is still under development.